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sense and simplicity

LED System Solutions

Iain Black & Jim Neff
Philips Lumileds Manufacturing
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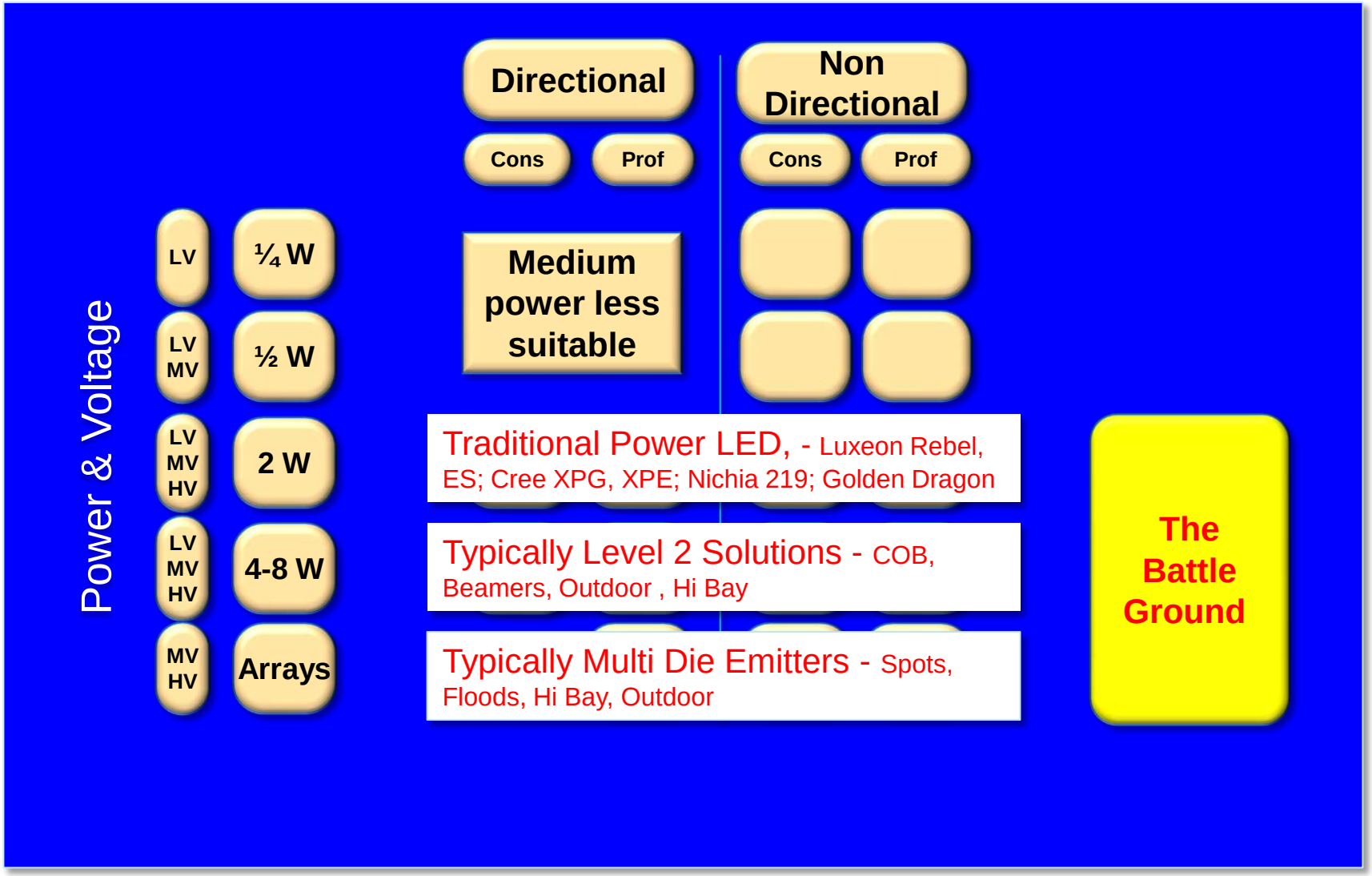
The Illumination Space…



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Medium vs. High Power LEDs

Assumptions:

- Mid-power LEDs lag high-power in lm/W
  - The last 2 years have clearly proven that this is no longer a safe assumption.
  - Assume existence of general equivalence among main players in omnidirectional solutions
- At optimum drive currents, mid-power LEDs lag high-power in lm/$
  - This continues to be true: drive current limitations in medium power packages means that high power LEDs driven at 2-3W can provide superior emitter lm/$
  - However, system limitations can significantly limit this advantage
- Mid-power LEDs lag high-power in system lm/$
  - Too general a statement – the relative system value is much less clear and heavily design dependant

System Value

Mid-Power

- Uniformity
  - *Sources can be spread around particularly for TLED etc…*
- String Voltage
  - *Driver compatibility*
- Redundancy
  - *Relative ease of providing redundancy compensates for lower reliability*
- Simplicity of Use
  - *Cheap level-2, even COB*
- **Mitigations**
  - *Smaller packages/COB*
  - *Improved reliability*

High-Power

- Compact
  - *Small footprint for tight spaces*
- High Flux
  - *Higher Lumen packages easier to realize with power LED*
- Reliability
  - *Higher reliability*
  - *Lumen Maintenance*
- High Directionality & Punch
- **Mitigations**
  - *String voltage: multi junction solutions*
  - *Smaller die sizes*
  - *Improved reliability*

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Other Applications

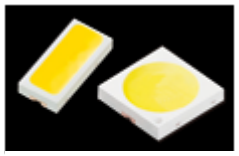
- **Display (Mid-power)**
  - A lost cause for hi-power?
- **Flash (High-power)**
  - High surface brightness and punch requirements make this a very directional solution, therefore unsuitable for today's mid-power solutions
- **Automotive Exterior Lighting (High-power)**
  - High surface brightness and punch requirements make these very directional solutions, therefore unsuitable for today's mid-power solutions

Test & Measurement

- Problem: Cost of 100% electro-optical testing has not kept pace with other mfg cost reductions
  - Testing is necessary, but does not add value
  - Electrical test very cheap, but optical adds complexity & cost
- Desired solutions:
  - Better test equipment to enable cheaper testing, especially hot test
  - Better algorithms to avoid 100% test & binning
  - Tighter process control of color, flux, voltage distributions to enable test simplification
  - Simpler methodology for calibration, both individual tester and across fleet
  - Optical test capability on-par with state-of-art electrical testing

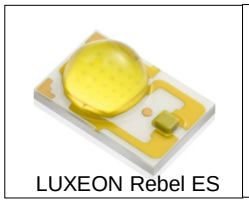
Flexible Packaging

- Today, package form/fit is designed around LED chip architecture
  - Asia mfgs: mid-power, lateral die 5-sided emitters → PLCC cups
  - USA mfgs: high-power, surface emitters → die on ceramic, others
- Common (standardized) packages will inevitably serve some die architectures better than others
  - PLCC footprints serve mid-power (Asia) well, disadvantageous to high-power (USA)
  - Array packaging accommodating to either mid- or high-power
- How do we get packaging standards that work for high-power?
  - Need more affordable materials that don't sacrifice reliability or performance
  - Less material leads to lower cost

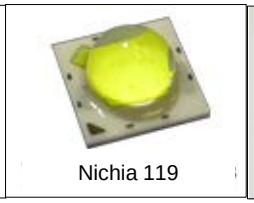


Nichia 157, 757

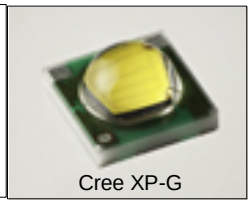
Samsung MP56L



LUXEON Rebel ES



Nichia 119



Cree XP-G

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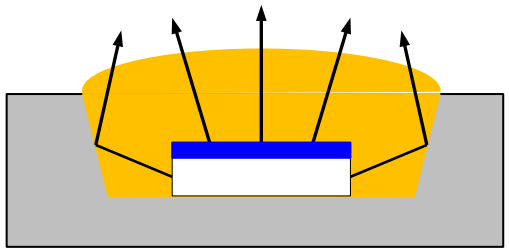
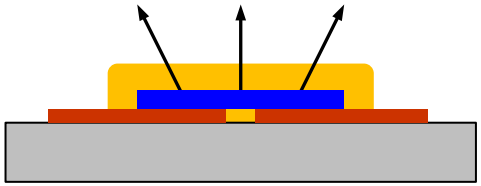
Phosphor Solutions

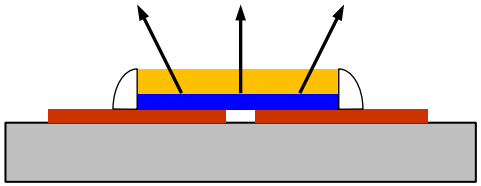
- Problem: Phosphor solutions are a significant portion of packaging cost
  - Phosphor & matrix materials; application technology and process control
  - Mid-power has cheap solution (goopinacup), but not suitable for high-flux, tight binning
- Need: Low-cost phosphor solutions for high-power LEDs
  - Phosphor materials may not dominate phosphor system cost
  - Tight control of thickness & volume (tight binning) are required
- High-power tradeoffs
  - Flux density vs. material volume, CE (direct vs. remote phosphor solutions)
  - Material cost vs. reliability, CE, temperature performance



Goop



Mold or Film



Plate

Conclusion

- In the non-directional battleground for high volume illumination, very low cost mid-power LEDs offer an excellent proposition, in particular where a distributed light source is desired (e.g., TLED)

- In space-constrained applications, high-power LEDs offer form factors which are difficult to meet with mid-power solutions (especially high-lumen packages)

- In the mass A-type bulb space, considerations over system design, including phosphor strategy, heat sink design, and driver create a space which can be addressed by either solution and, thus, is where the lines are most blurred

- Disruptive factors include: regulation *(Energy Star specs, etc…),* excess display capacity dumped into illumination, use of hybrid white LEDs (white + red), and remote phosphor designs